



# Application of Shine Dispersion to Identify Plastic Debris at Extremely Low Aqueous Concentrations in Ocean Water

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## ABSTRACT

The detection and quantification of microplastics in the marine environment is essential for understanding the overall impact of plastic pollution on ecosystems and human health. Here we investigate the ability to detect very low concentrations of colloidal particles with diameter  $d=0.1\ \mu\text{m}$ - $0.8\ \mu\text{m}$  in seawater using Static Light Scattering (SLS) and Dynamic Light Scattering (DLS) techniques. The detection limit of the instrument was determined using monodisperse spherical polystyrene latex model particles of  $0.2\ \mu\text{m}$  and  $0.5\ \mu\text{m}$  diameter. Colloid concentrations and sizes have been shown to be measurable down to about  $10\ \text{g/L}$ - $6\ \text{g/L}$ . Light scattering measurements of seawater from various locations in Western Europe showed that DLS detected colloidal particles in filtered seawater with a pore size of  $0.8\ \mu\text{m}$ . These particles had concentrations below  $1\ \mu\text{g/L}$  and average diameters of approximately  $0.6\ \mu\text{m}$ . We emphasize that these particles are not necessarily made of plastic. No particles were detected after filtration.

**Keywords:** Microplastics; Seawater; Colloids; Static light scattering; Dynamic light scattering

## INTRODUCTION

The fate of plastics that end up in the ocean is currently receiving a great deal of attention. Once released into the environment, plastics are subject to mechanical (erosion, abrasion), chemical (photooxidation by UV radiation, hydrolysis) and biological (degradation by microorganisms) [1]. This leads to accelerated ageing and fragmentation of macroplastics to produce microplastics, defined as plastic particles smaller than 5 mm. Microplastics are found to be ubiquitous in the environment, especially on the ocean surface. An important question that has recently emerged is whether microplastics will continue to break down into colloidal particles with diameter  $d<.1\ \mu\text{m}$ , which is often called a nanoplastic [2]. However, some authors consider

plastic particles less than 100 nm in diameter to be nanoplastics or use the term microplastics. For simplicity, we will call the particle  $d<.1\ \mu\text{m}$  was detected in this nanoplastic study [3].

## LITERATURE REVIEW

We investigated the release of nanoplastics under UV light from weathered polyethylene and polypropylene debris from the environment. They observed that nanoplastics of various sizes were produced over several weeks [4]. More recently, I studied seawater pooling near the surface of subtropical gyres in the North Atlantic. Particles from 1 nm to  $1\ \mu\text{m}$  in diameter were detected in 200-fold concentrated seawater. It has been suggested that these particles are primarily nanoplastics

<b>Received:</b>	14-June-2023	<b>Manuscript No:</b>	AASRFC-23-17601
<b>Editor assigned:</b>	19-June-2023	<b>PreQC No:</b>	AASRFC-23-17601 (PQ)
<b>Reviewed:</b>	03-July-2023	<b>QC No:</b>	AASRFC-23-17601
<b>Revised:</b>	18-August-2023	<b>Manuscript No:</b>	AASRFC-23-17601 (R)
<b>Published:</b>	15-September	<b>DOI:</b>	10.36648/0976-8610.14.3.113

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**Citation:** Tunsen R (2023) Application of Shine Dispersion to Identify Plastic Debris at Extremely Low Aqueous Concentrations in Ocean Water. Adv Appl Sci Res. 14:113.

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formed by the decomposition of microplastics, but the authors do not provide an estimate of the concentration of nanoplastics in seawater.

The presence of such small particles raises questions about their concentration in the environment and their potential for accumulation in trophic chains. In fact, due to their small size and special properties, nanoplastics can be taken up by a wide range of aquatic organisms and interact with membranes and cells [5]. Nanoplastics dispersed in seawater may be part of 'missing plastics' that were dumped into the ocean but are no longer observed on the surface. Therefore, detection and quantification of nanoplastics in all aquatic compartments is urgently needed. The big problem is that the concentration of nanoplastics in seawater is still expected to be very low, despite the huge amount of plastics in the ocean.

Static and dynamic light scattering techniques have the potential to determine both the average size and concentration of colloidal particles, even when they are present at very low concentrations [6]. First, we critically evaluate the potential of these light scattering techniques for quantifying the concentration and size distribution of model nanoplastics in the morphology of polystyrene latex particles with  $d < 0.8 \mu\text{m}$  dispersed in water. We then describe light scattering measurements of seawater sampled from various locations near the coast of Western Europe. Indicates the presence of a colloidal concentration. The concentration of colloid is  $0.45 < 0. d < 0.8 \mu\text{m}$  corresponds to about  $1 \mu\text{g/L}$  and can be carefully characterized. Of course, mineral colloids are also thought to be present, so colloids detected in seawater are not necessarily made of plastic. The discussion section discusses how light scattering results depend on material type [7].

For  $q > d^{-1}$ ,  $R\theta$  decreases rapidly with increasing  $q$ , so that for  $q > 2 \times 10^7 \text{ m}^{-1}$  ( $\theta > 70^\circ$ ), the suspension of smaller particles is actually more. It is important to realize that the than larger particles of the same concentration. The scattering intensity of small latex suspensions was much larger than that of water up to  $C = 10^{-5} \text{ g/L}$  over the entire available  $q$  range. The intensity of scattering by a homogeneous suspension of spherical particles at a constant mass concentration increases with increasing size of  $q \times d < 1 > 1$ . For a given value of  $q$  and  $C$ ,  $R\theta$  is maximized for particles with  $d \approx 2\pi/q$ . Therefore, when examining very low concentrations of large particles, light scattering measurements should be performed with small  $q$ -values. In this case  $q > 2 \times 10^7 \text{ m}^{-1}$ , *i.e.*,  $\theta > 70^\circ$ , but scatters orders of magnitude more light than water even at smaller angles.

As was Milli-Q water with adequate amounts of sea salt over the entire  $q$  range. Considering the model latex particle results described in the previous section, such results are obtained for suspensions of latex particles with  $d = 0.2 \mu\text{m}$  only when  $C < 1 \mu\text{g/L}$ , and  $0.1 \mu\text{g/L}$  for particles with  $d = 0.5 \mu\text{m}$  only if  $C < 1 \mu\text{g/L}$ . In conclusion, particle concentrations in this seawater sample with  $d$  between  $0.2 \mu\text{m}$  and  $0.45 \mu\text{m}$  were less than  $1 \mu\text{g/L}$ . It is assumed that the refractive index increase and particle density are close to those of polystyrene. This means, this is true for most types of nanoplastics. Of course, this does

not exclude the presence of smaller particles at higher concentrations. For example, the overscattering intensity of a very dilute particle suspension with  $d = 20 \text{ nm}$  at the same mass concentration is 1,000 times lower than with  $d = 0.2 \mu\text{m}$ .

## DISCUSSION

Here we use static and dynamic light scattering to detect colloidal particles in aqueous suspensions, provided that the colloidal particles scatter more significantly than water and the scattering volume contains at least a few tens of particles [8]. It was shown that it is possible to characterize them quantitatively. These limits depend on colloid size, shape, polydispersity and refractive index increment. Could be reliably characterized by static light scattering up to  $C = 10 \mu\text{g/L}$ . By static light scattering measurements down to  $C = 1 \mu\text{g/L}$ , whereas DLS can only be characterized up to  $C = 10 \mu\text{g/L}$  [9]. Of course, there is no sharp boundary between concentrations characterized and not characterized by light scattering techniques. As it happens, the lower the concentration, the less reliable the results.

In seawater samples, we found that the concentration of colloids  $0.2 \mu\text{m} - 0.8 \mu\text{m}$  in diameter did not exceed  $1 \mu\text{g/L}$  as long as they had the same refractive index gradient and density as polystyrene [10]. This concentration was just sufficient for quantitative characterization by light scattering. The splattering amount of seawater filtered through  $0.45 \mu\text{m}$  pores was within experimental error, as was the case with salt water. This means that the intensity measured in  $0.8 \mu\text{m}$  filtered seawater is due to scattering by colloids with diameters from  $0.45 \mu\text{m}$  to about  $0.8 \mu\text{m}$  [11].

It is possible that the colloids found in the seawater samples investigated here were not all nanoplastics. Therefore, it is necessary to consider how the light scattering results depend on the material type. The radius of gyration and hydrodynamic radius are independent of the material. However, the light scattering intensity of particles of a given size and weight concentration is proportional to the density of the particles and the square of the refractive index increase. Therefore, if we assume that the particles are made of minerals rather than plastics, the estimated particle concentrations would be even lower [12]. This study confirms that the detection and identification of nanoplastics in the environment is a very challenging research area. This requires the separation of sufficient colloidal particles from large volumes of seawater so that they can be analyzed after pyrolysis using techniques such as Raman scattering and combined gas chromatography and mass spectrometry. The challenge is to remove all non-colloidal material without introducing extraneous colloids during the separation process [13].

## CONCLUSION

The light scattering intensities of seawater samples collected from various locations off the coasts of Western Europe and the mediterranean and filtered through a  $0.45 \mu\text{m}$  pore size

filter were similar to those of pure water spiked with the same amount of sea salt as. Similarly, it was within experimental error seawater. Concentrations of colloidal particles 0.2  $\mu\text{m}$ -0.45  $\mu\text{m}$  in diameter in seawater samples were found to be less than 1  $\mu\text{g/L}$  by comparison with colloidal model particles. Colloidal particles were detected in seawater filtered through a filter with a pore size of 0.8  $\mu\text{m}$ , but the concentration was less than 1  $\mu\text{g/L}$ . Measured dynamic light scattering showed that the particles had a size distribution with an average hydrodynamic diameter of 0.6  $\mu\text{m}$ . The concentration of colloidal particles in seawater samples is too low to characterize their composition. Measurements of colloidal model particles show that the characterization of colloidal particles in seawater requires the use of state of the art light scattering instruments that allow measurements as a function of the scattered wave vector.

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